MSU CALIBRATION

1. Introduction

The Microwave Sounding Unit (MSU) on the current NOAA series of polar-orbiting environmental satellites (POES) is a four-channel Dicke radiometer consisting of two scanning reflector antenna systems, each of which provides two channels. The MSU antenna system requires to have a nominal beam width of 7.5° at the half-power points and to cover a crosstrack scan of ±47.4° (to beam centers) from the nadir direction with 11 Earth-view positions, each separated by 9.47°. Beam positions 1 and 11 are the extreme scan positions of the Earth views, while beam position 6 is at the nadir direction. Onboard blackbody and cold space calibrations are performed once every 25.6 seconds for each scan line. The main MSU characteristics are given in Table 1. The detailed functional description of the MSU system can be found in [1] and only a brief summary is given here.

Microwave energy received by each antenna is separated into vertical and horizontal polarization components by an orthomode transducer. Each of the four signals (from two antenna systems) is then fed to one of the MSU channels. Each channel is identical except for the operating frequency.

Table 1. MSU Characteristics.

Characteristics	**Channel**			
	1	**2**	**3**	**4**
Frequency (GHz)	50.30	53.74	54.96	57.95
RF bandwidth (MHZ)	220	220	220	220
NEΔT (K)	0.3	0.3	0.3	0.3
Resolution at nadir (km)	105	105	105	105
Number of Earth views	11	11	11	11
Scan width from nadir	±47.4°	±47.4°	±47.4°	±47.4°
Antenna beamwidth	7.5°	7.5°	7.5°	7.5°
Antenna beam efficiency	>90%	>90%	>90%	>90%
Polarization at Nadir	V	H	V	H
Integration time (second)	1.84	1.84	1.84	1.84

The incoming signal is connected to a Dicke switch, which switches between a microwave load at instrument temperature and the incoming signal. This modulated switch output (signal) is passed through an isolator and then mixed in a low noise balanced mixer with a local oscillator (LO) signal to produce an IF frequency with a pass band of 10-110 MHZ. The signal is further amplified in the post IF and video amplifiers and then demodulated by the phase detector. The final signal amplification takes place in the integrator and dc amplifier. This output signal is digitized by a 12-bit analog-to-digital (A/D) convertor, stored and then sent to the ground station together with other spacecraft data.

2. ***Algorithm of MSU Calibration***

Prelaunch calibrations of the MSU instruments were performed in a thermal vacuum chamber by its manufacturer, the Jet Propulsion Laboratory (JPL). The National Environmental Satellite, Data, and Information Service (NESDIS) and JPL independently analyzed the data from the prelaunch tests to determine the instrument characteristics, such as accuracy, sensitivity (NEΔT), and nonlinearity for each MSU instrument.

A linearized MSU calibration algorithm is described in [2], which gives the Earth-view radiance, R_s, in term of the “modified” Earth-view counts C_s',

$$R_s = R_c + \frac{R_w - R_c}{\overline{C_w'} - \overline{C_c'}}\left(C_s' - \overline{C_c'}\right) \tag{1}$$

where the R_w and R_c are the radiances corresponding to the internal blackbody target temperature T_w and the effective cold space temperature T_c, respectively. The modified Earth-viewing counts C_s' is defined as,

$$C_s' = d_0 + d_1 C_s + d_2 C_s^2 \tag{2}$$

where C_s is the raw count (i.e., radiometric count) from the Earth scene. The coefficients d_i (where i=0, 1, and 2) represents the nonlinearity correction coefficient, which is determined from the analysis of the prelaunch test data. The $\overline{C_c'}$ and $\overline{C_w'}$ are the averages of the C_c' and C_w' over 25 scan lines (12 lines prior to and 12 lines subsequent to the current line for which the coefficients are being calculated). Similar to Equation (2), the C_c' and C_w' are the modified radiometric counts of the cold space and internal blackbody target, respectively, and are defined as follows,

$$C_c^{/} = d_0 + d_1 C_c + d_2 C_c^2 \qquad \textbf{(3)}$$

and

$$C_w^{/} = d_0 + d_1 C_w + d_2 C_w^2 \qquad \textbf{(4)}$$

where C_c and C_w are the raw counts of the cold space and internal blackbody target, respectively. Equation (1) can be written in the form[1],

$$R_s = I + M C_s^{/} \qquad \textbf{(5)}$$

where the slope M and intercept I are given by,

$$M = \frac{R_w - R_c}{\overline{C_w^{/}} - \overline{C_c^{/}}} \qquad \textbf{(6)}$$

$$I = R_c - M \overline{C_c^{/}} \qquad \textbf{(7)}$$

Equation (5) shows that the Earth-view radiance R_s is a linear function of the modified Earth-view count $C_s^{/}$.

3. ***NOAA Level 1B Data***

The NOAA Level 1b data are raw data that have been quality controlled, assembled into discrete data sets, and to which Earth location and calibration information were appended but not applied. In the MSU 1b datasets, values of the intercept I and slope M are calculated and listed for each scan line. The nonlinearity correction coefficients d_i (with I=0, 1, and 2) are also listed in the 1b datasets.

---

[1] Equations (3) and (4) were not implemented in the NESDIS Operations as described in [3]. Then $C_c^{/} = C_c$ and $C_w^{/} = C_w$ are used in Equations (1), (6), and (7).

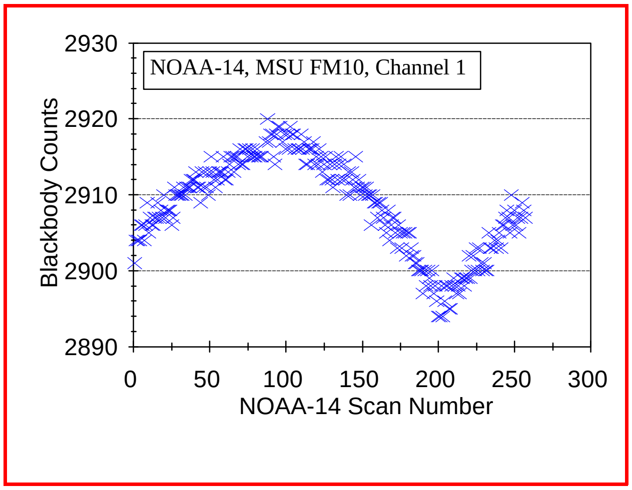

Figure 1. Samples of NOAA-14 MSU data: Blackbody counts over one orbit.

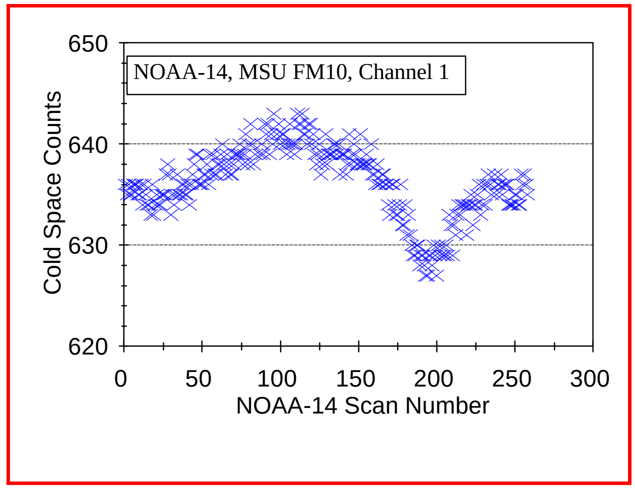

Figure 2. Samples of NOAA-14 MSU data: Cold space counts over one orbit.

4. ***NOAA Satellite Active Archive***

The NOAA Satellite Active Archive (SAA) is an on-line service provided by NESDIS. The NOAA satellite data can be accessed through Internet. The SAA Internet address is:

http://www.saa.noaa.gov

Some samples of the NOAA-14 MSU data are shown in Figures 1-3. In Figure 1, the blackbody radiometric counts from Channel 1 versus the scan number within one orbit are shown. Figure 2 shows the corresponding cold space counts from the same orbit.

Figure 3 shows the NOAA-14 MSU data of brightness temperatures from one scan line over ocean on January 27, 1997. The 11 data points constitute a complete angular distribution covered by the MSU measurements over one cross scan of the Earth scenes. For comparison, the results calculated from the radiative transfer equation and an oceanic emissivity model are also shown.

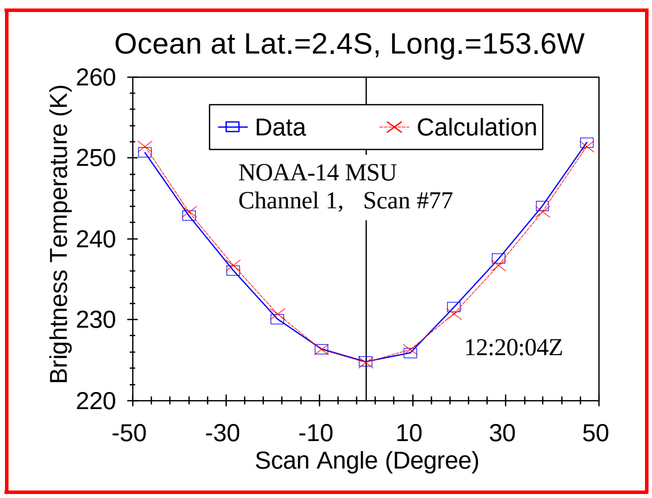

Figure 3. Brightness temperatures measured by MSU over one scan line.

REFERENCES

[1]. H. G. Homan and F. Soltis,“TIROS-N Microwave Sounder Unit (MSU) - Detail Specification,” JPL SPEC ES511746A, Jet Propulsion Laboratory, Pasadena, CA, 1977.

[2]. W. G. Planet, editor, "Data Extraction and Calibration of TIROS-N/NOAA Radiometers," NOAA Tech. Memo. NESS 107, Rev. 1, Washington, D.C. 20233, 1988.

[3]. M. P. Weinreb, "MSU Calibration Processing and Biases between NOAA-10 and NOAA-12 Observations," NESDIS Memorandum, Washington, D.C. 20233, October 1991,